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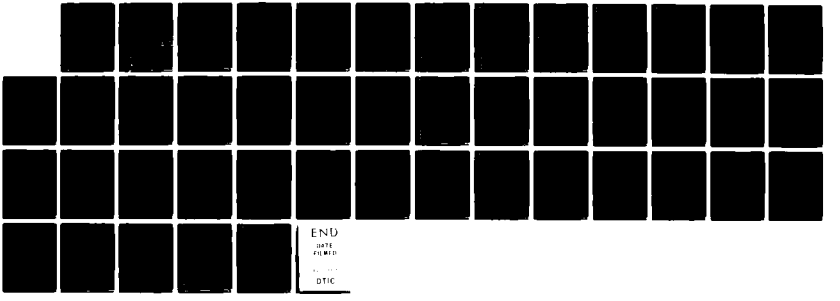

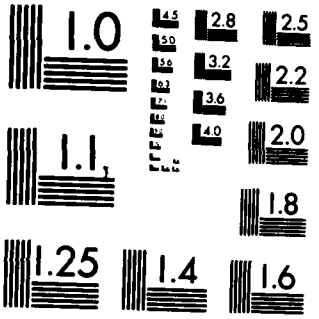

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EVALUATION OF THE TRI-SERVICE LABORATORY SYSTEM.

COST/BENEFIT ANALYSIS OF TRILAB SYSTEM NRMC OAKLAND

ARTHUR D. LITTLE, INC.
Acorn Park
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Final Report for Period 2/17/82-5/15/83

Prepared for

TRIMIS Program Office
5401 Westbard Avenue
Bethesda, MD 20816

Arthur D Little, Inc.

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Cost/benefit analysis of clinical laboratory system at NRMC Oakland.

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I. INTRODUCTION

A. BACKGROUND

This report presents a cost/benefit evaluation of the Tri-Service Laboratory (TRILAB) System installed at the Naval Regional Medical Center (NRMC) Oakland.

NRMC Oakland was the first facility to receive the TRILAB system and was chosen as the primary evaluation site for the system. TRILAB was also implemented in two other sites: Dwight D. Eisenhower Army Medical Center (DDEAMC), Augusta, Georgia; and Wright Patterson Medical Center and Regional Hospital, Dayton, Ohio. The evaluation was based primarily on data collected at NRMC Oakland during evaluations of laboratory services before and after implementation of TRILAB, but inputs from the other two sites were used where available for confirmation.

The original evaluation plan for the TRILAB system was developed by Analytic Services, Inc. (ANSER), in 1980. Baseline data were collected under the supervision of ANSER staff during an eight-week period (September 29, 1980-November 29, 1980).

Implementation of the TRILAB system at NRMC Oakland was initiated in February 1982. The basic data for the post-implementation evaluation were collected during an intensive study period, October 8-22, 1982. In addition to data collection and interviews during this study period, three implementation monitoring visits were made prior to the study period (March, May and August, 1982), during which laboratory staff and providers were interviewed. The results of the two studies were summarized in "Evaluation of the Tri-Service Laboratory System, Volume II," Arthur D. Little, Inc., January 21, 1983 (draft report)[1]. The cost/benefit analysis presented here is based primarily on data and information presented in this report.

The TRILAB system is designed to support the following laboratory activities: patient files, test order entry, specimen accessioning and control, work document preparation, quality control, test result entry, inquiry and data retrieval, test result reporting at wards and

clinics, and management reporting. The TRILAB system has the capability to interface automated, high-volume test instruments on-line, with the goal of significantly reducing clerical work of laboratory technicians and transcription errors. The system is also designed to monitor quality control samples in order to check for correct calibration of instruments and proper handling of the specimens within the laboratory, and to produce interim test results reports, daily cumulative reports, and cumulative summary discharge reports.

The system supports terminals outside the laboratory, such as in wards, clinics and satellite facilities, for transmission of results and for inquiry as to test status. In addition, the system produces management information, such as laboratory workload summary reports, in order to reduce the effort to prepare management reports and to assist in the efficient organization and administration of the laboratory.

NRMC Oakland is a large medical treatment facility (MTF), with an average daily inpatient census of 244 patients and service volume of 376,326 outpatient visits per year (FY 1982). During FY 1982, the clinical laboratory performed approximately 2,586,000 tests (including quality controls) compared with 2,642,000 tests in 1980. Laboratory workload thus remained relatively stable between the baseline and post-implementation periods. During October 1982, when the post-implementation data collection effort was carried out, the laboratory performed 170,150 patient tests (excluding quality control). This is 15 percent greater than the 147,625 tests reported performed in October 1980 (when the baseline survey was carried out). Assigned clinical laboratory staffing was 90 FTEs during both the baseline and post-implementation periods.

B. APPROACH

The approach to the cost/benefit analysis was that of estimating total incremental life-cycle costs and benefits over the period of the contract, eight years; that is, the additional costs and benefits attributable to the TRILAB system. The one-time and recurring costs associated with the acquisition and implementation of the TRILAB system were identified and estimated, using contract documents. Estimates provided by the facility were used for different elements

of implementation costs. Benefits were estimated by comparison of activities in the laboratory and in provider locations affected by implementation of the system, from work sampling and observation studies, and by interviews. The majority of quantifiable benefits resulting from the system were in the form of personnel time savings. These personnel resources saved through implementation of the TRILAB system have not necessarily resulted in fewer FTEs employed in the hospital, but in most instances have resulted in increased time made available to meet increased demand for services or to provide more directly related patient care activities. Thus, the value of the time freed up (measured by the associated hourly salaries and fringe benefits) was considered a benefit of the system.

In addition to those benefits which could be quantified, there were a number additional benefits which could improve patient care or possibly result in cost savings, but could not be estimated or quantified. These were summarized as "non-quantifiable benefits."

The next chapter summarizes the incremental costs and benefits due to the TRILAB system and a base-case life-cycle cost/benefit analysis. The base case incorporates the best estimates of costs and quantifiable benefits and assumptions with regard to appropriate inflation and discount rates. Chapter III presents the results of several sensitivity analyses, which test the effect of alternative inflation and discount rates, equipment configuration and benefit estimates.

C. SUMMARY OF FINDINGS

The base-case life-cycle analysis shows that the TRILAB system installed at NRMC Oakland is very cost effective. Life-cycle benefits of $2.6 million exceed life-cycle costs of $1.9 million by $750,000. Approximately 10 percent of quantifiable benefits were obtained within the laboratory and 90 percent outside the laboratory, in patient care areas. In addition, there were a number of benefits which could not be quantified, including:

- improved turnaround time for test results, which had the potential for improving patient care and reducing length of stay;
- improved and easier availability of test results to providers, which improved relationships between providers and laboratory staff;
- improved and more useful report formats, such as cumulative reports and highlighting abnormal results, which could improve patient care; and
- increased laboratory management reporting capability, which could improve overall effectiveness of laboratory operations.

Sensitivity analyses show that in general the positive net benefits are increased by different assumptions with regard to assumed inflation or discount rates, terminal configuration, or growth in annual number of tests. The only change in estimates or assumptions which reduced benefits was a decrease in personnel time savings outside the laboratory (in wards and clinics); if these time savings were decreased by 50 percent, then life-cycle costs exceeded quantifiable life-cycle benefits.

II. COST/BENEFIT ANALYSIS OF TRILAB SYSTEM NRMC OAKLAND

This chapter presents a life-cycle analysis of the incremental costs and benefits of the TRILAB system installed at the Naval Regional Medical Center, Oakland.

The majority of the data used in this analysis was obtained from a previous report entitled, "Evaluation of the Tri-Service Laboratory System, Volume II, Naval Regional Medical Center, Oakland," which was submitted to the TRIMIS Program Office in draft form on January 21, 1983. Other inputs were obtained from the evaluations at DDEAMC and Wright Patterson.

A. SYSTEM COSTS

The following estimates of costs of the TRILAB system were based on three sources: the vendor proposal for the system at NRMC Oakland, the monthly material inspection and receiving reports for the lease and maintenance of the systems, and interviews held with systems, laboratory and nursing staffs of the hospital.

Costs of the system were divided into one-time costs (including system acquisition, site preparation, set-up and training costs), and recurring costs (including system operations staff, data processing supplies, system maintenance and space costs).

1. One-Time Costs

a. System Acquisition

The laboratory system was purchased under a 13-month least-to-ownership plan at a monthly charge of $39,182. The total cost of the hardware system, including mainframe and peripherals (42 CRTs, 7 character printers and 1 line printer) was 13 months x $39,182/month = $509,366. Other one-time vendor charges were:

System installation	$ 48,895
Software	$188,897
Documentation	15,790
Training	21,053

The total system acquisition cost was therefore $784,001.

b. Site Preparation

The cost of preparing a computer room for the TRILAB and other computer systems was $163,000. In addition, it was planned to upgrade the air-conditioning and power supply to the computer room in December 1982; the cost of site upgrade was estimated at $165,000. Total cost of preparation for automation was therefore $328,000. Since the computer room will support several computer systems, 30% of the site preparation costs were allocated to TRILAB. Total site preparation cost was therefore estimated at $100,000.

c. Other Equipment

The MIS Department purchased additional anchors for the terminals ($806) and video tape ($453) for the system, for a total of $1,259.

d. Systems Staff

During installation and implementation of the system, six man-months of analysts were involved (four man-months of an analyst GS-11 and two man-months GS-12): (4 x $3,179*) + (2 x $3,560*) = $19,836.

e. Training Time

The following categories of hospital staff received training on use of the system, during their normal duty hours. The estimated costs of the staff time involved are presented below:

Computer Operators. Five computer operators (GS-7 level) received 24 hours of training each. The staff time salary cost therefore was: 5 x 24 x $12.39* = $1,487.

*Civilian salaries from Federal Employees' Salary Scale. Ranks used were GS-4 = ward clerk; GS-7 = LPN; GS-11 = RN (all step 4). Includes leave allowance of 20.9% and fringe of 21.7%. Military salaries include base pay from annual composite salary schedule. Ranks used were E-1 = ward clerk; E-4 = non-RN; O-1 = RN. Rates were adjusted by leave allowance of 20.9% and 38% fringe plus quarters and other special pays. The value of time for RNs and ward clerks was calculated at 25% civilian and 75% military. Corpsmen were assumed to be 100% military and LPNs 110% civilian. A composite military nursing staff was developed from data on staffing mix collected at three medical facilities (William Beaumont Army Medical Center, Naval Regional Medical Center at Jacksonville, and United State Air Force Regional Hospital at Eglin) during FY 1982. The actual mix of laboratory personnel at NRMC Oakland was used to calculate an average laboratory salary.

Laboratory Staff. Approximately 45 laboratory staff received about five hours of training each on use of the system, for a total of 225 hours. In addition, senior laboratory staff spent approximately 70 hours in training physicians to use the terminals for inquiry, on a one-on-one basis. The total estimated time cost was 295 x $11.01 = $3,248.

Nursing Staff. One hundred-eleven members of the Nursing Department staff received one hour of formal training each. At an average hourly salary of $12.68, the salary time cost was 111 x $12.68 = $1,407.

Physicians. As discussed above, approximately 70 physicians received one-on-one training from laboratory staff. Assuming an average 0-4 grade and one hour of training, the time cost involved was 70 x $30.31 = $2,122.

Total. The total estimated cost of staff time involved in training was therefore $8,264.

f. File Building

Laboratory staff time involved in building the initial data files was estimated to total 120 man-days. At an average daily cost of $88.15, the total staff time costs was 120 x $88.15 = $10,578.

g. Total

The total one-time cost for installation and implementation of the TRILAB system at NRMC Oakland, as summarized in Table 1, was $923,938.

2. System Operating Costs

a. System Maintenance

Initial monthly system maintenance costs were:

Hardware	$2,148
Software	1,390
Communication Lines	558
Total	$4,096

Hardware maintenance was scheduled to increase annually by 7 percent, 7 percent, 9 percent, 9 percent, 12 percent, 13 percent, and 14 percent on July 1, 1982 through July 1, 1988. Communication line

TABLE 1

ONE-TIME TRILAB SYSTEM IMPLEMENTATION COSTS
NRMC OAKLAND

Cost Item	Cost
System Acquisition	$784,001
Site Preparation	100,000
Other Equipment	1,259
Systems' Staff	19,836
Staff Training Time	8,264
File Building	10,578
Total	$923,938

maintenance cost was scheduled to escalate at 10 percent per annum commencing July 1, 1982. Software maintenance costs were not subject to escalation. The projected schedule of maintenance costs is shown in Table 2.

b. Space Costs

The allocated annual space cost for the computer room at NRMC Oakland was $5.71/sq. ft. for 1,560 sq. ft., or $8,908. There are currently three computer systems; it is planned that there will be ten systems within four years. The space costs were therefore estimated at $2,969 annually for the first three years and $891 per year thereafter.

c. Staff Costs

Analyst. A full-time analyst (GS 11) was devoted to the maintenance of the system. The annual costs were therefore $38,142.

Operators. The equivalent of 56 hours per week of operator time (GS 7) were allocated to the system. The annual cost was therefore 52 weeks x 56 hours x $12.39 = $36,080.

The total annual system staff costs were therefore $74,222.

d. Supplies

Estimated costs of supplies (primarily computer report paper) were $14,000.

3. Summary of Costs

Table 3 summarizes the estimated annual (non-inflated and undiscounted) recurring costs for 1982-1990. The projected annual increases in hardware maintenance were included, but no other inflation factors were taken into consideration in these calculations. Annual recurring costs were estimated to increase from $140,000 per year to $169,000 per year during this period.

Table 4 summarizes the total (undiscounted and non-inflated) costs of the system over the eight-year contract period taken as the life-cycle of the system. The system is estimated to cost approximately $2.2 million over the eight-year period, or approximately $250,000 per year, for acquisition, installation and operation.

TABLE 2

ANNUAL TRILAB COMPUTER MAINTENANCE COSTS
NRMC OAKLAND

FY	Hardware	Software	Line	Total	Annual
1982 (6 mos.)	$2,148/mo.	$1,390/mo.	$558/mo.	$4,096/mo.	$24,576
1983	2,298	1,390	614	4,302	51,624
1984	2,459	1,390	675	4,524	54,288
1985	2,681	1,390	743	4,814	57,768
1986	2,922	1,390	817	5,129	61,548
1987	3,272	1,390	899	5,561	66,732
1988	3,698	1,390	989	6,077	72,924
1989	4,216	1,390	1,087	6,693	80,316
1990 (6 mos.)	4,806	1,390	1,196	7,392	44,352
					$514,128

TABLE 3

ANNUAL RECURRING TRILAB SYSTEM COSTS
NRMC OAKLAND--1982-1990
(not inflated or discounted)

FY	Maintenance[1]	Space	Systems' Staff	Supplies	Total
1982 (6 mos.)	$24,576	1,485	$37,111	$ 7,000	$ 70,172
1983	51,624	2,969	77,164	14,000	145,757
1984	54,288	2,969	77,164	14,000	148,421
1985	57,768	891	77,164	14,000	149,823
1986	61,548	891	77,164	14,000	153,603
1987	66,732	891	77,164	14,000	158,787
1988	72,924	891	77,164	14,000	164,979
1989	80,316	891	77,164	14,000	172,371
1990 (6 mos.)	44,352	446	38,582	7,000	90,380
					$1,254,293

1. As specified by contact

TABLE 4

TOTAL TRILAB SYSTEM COSTS
NRMC OAKLAND--1982-1990
(not inflated or discounted)

FY	Recurring Costs	One-Time Costs	Total
1982 (six mos.)	$ 70,172	$923,938	$ 994,110
1983	145,757		145,757
1984	148,421		148,421
1985	149,823		149,823
1986	153,603		153,603
1987	158,787		158,787
1988	164,979		164,979
1989	172,371		172,371
1990 (six mos.)	90,380		90,380
One-Time Costs	$1,254,293	$923,938	$2,178,231

B. QUANTITATIVE BENEFITS OF TRILAB SYSTEM

On July 15, 1977 the TRIMIS Medical Review Group (MRG) developed seven project objectives for the Tri-Service Laboratory System:

- To make information available to physicians with increased efficiency and accuracy;
- To present the data in a convenient and meaningful manner with sufficient variety in report formats to meet the needs of all users;
- To be able to handle increased demands for laboratory tests without significant increases in staff;
- to provide accountability of laboratory requests and to monitor generation of test results to include providing notices of abnormal values or improper quality control results as soon as they are available;
- To gather, as a result of normal procedures, workload and managerial data, and to present this as required in order to assist in decision-making in the laboratory;
- To reduce the clerical work required of qualified technicians in the laboratory;
- To improve result accuracy by eliminating transcription, calculation, and specimen identification error.

In this section, estimates of those benefits attributable to the TRILAB system which can be quantified are presented. The benefits are divided into (a) those achieved within the laboratory, and (b) those achieved outside the laboratory, in patient care areas.

1. Estimated Benefits in Laboratory

Estimates for benefits in the laboratory were developed from two different sources: (1) data obtained from baseline and post-implementation work sampling studies, and (2) interviews with key staff in the laboratory.

a. Savings in Information Handling

Work Sampling Estimates. The work sampling studies estimated that the percentage of time devoted to information handling activities was 2.6 percent lower in the post-implementation period than in the baseline period, based on data collected during the day shift, Monday

through Friday. Assigned staff totaled 1,300 hours per week in the post-implementation period. From information obtained during the implementation monitoring visits, it was estimated that 80 percent of laboratory tests were performed during this time period. Assuming that the distribution of activities was the same on weekends as during midweek, the total number of laboratory staff hours saved per year was estimated as:

$$\frac{2.6\% \times 1300 \text{ hr/wk} \times 52 \text{ wks/yr}}{.80} = 2{,}197 \text{ hours}$$

The resulting figure was multiplied by an average hourly salary for the mix of staff in the laboratory, $11.01, for an overall estimated savings of $24,189.

Interview Estimates. Interviews with laboratory administration and supervisors were conducted and the following information handling areas were identified as having benefits derived from implementation of the TRILAB system:

- Workload Reporting. Laboratory supervisors estimated that 5.5 hours per week (442 hours per year) were being saved due to the TRILAB system producing the workload reports. Using the average salary of $11.01 per hour, the annual savings were $4,866.
- Quality Control. The amount of time saved by the computer system by producing quality control reports was estimated by staff members to be 11 hours per week (572 hours per year). This represents an annual savings of $6,298.
- Patient Exception Reports. It was estimated that approximately 10 hours per week (520 hours per year) were being saved by faster review of patient exception reports, due to the highlighting of abnormal results by the TRILAB system. The annual savings is thus $5,725.
- Telephone Calls. The reduction in laboratory staff time devoted to answering telephone inquiries was estimated as follows. During the baseline evaluation period, the laboratory performed 4,762 tests per day and received 102.4

calls per eight-hour day shift, while in the post-implementation period, the laboratory performed 5,489 tests per day and received 67.4 calls per eight-hour shift. According to data collected at Dwight D. Eisenhower Army Medical Center (DDEAMC), approximately two-thirds of all calls occur during the day shift. Therefore, it was estimated that there were approximately 154 calls per day (1 call per 31.0 tests) in the laboratory during the baseline evaluation period and 101 calls per day (1 call per 54.3 tests) during the post-implementation evaluation period.

Using the more recent workload figure of 5,489 tests, the number of calls per test using a manual system (1 call per 31 tests) would be equivalent to 177 calls per day for a similar workload, while in the post-implementation period it was 101 calls per day. The average time for each telephone call was estimated as four minutes. Therefore, the number of hours per day spent on the telephone during the baseline evaluation period and the post-implementation period was 11.8 hours and 6.7 hours respectively. This represented a savings of 5.1 hours per day, or 1,862 hours per year. Using the average salary of laboratory personnel of $11.01, the salary equivalent of time saved per year was $20,501.

- Total. The annual savings for information handling activities as estimated by laboratory staff, was $37,390.

Summary. The two estimates of time saved in information handling within the laboratory, of $24,189 from the work sampling studies, and $37,390 estimated from interviews, were averaged to arrive at an estimate of $30,790 for time saved in information handling activities (Table 5).

b. Reception Desk

Prior to implementation of the TRILAB system, staff at the reception desk were responsible for maintenance of filed test results, answering and forwarding telephone calls, and looking up test results.

TABLE 5

ESTIMATED ANNUAL SAVINGS DUE TO TRILAB SYSTEM
NRMC OAKLAND

Within Laboratory	
Information Handling	$30,790
Reception Desk	9,298
Reduction in Duplicate Tests	1,872
	41,960
Outside Laboratory	
Nursing Units	222,154
Outpatient Services	127,738
	349,892
Total Benefits	391,852

As a result of the reduced workload in these activities because of TRILAB implementation, it was possible to reduce the staff in the reception area by approximately one-half a person. Using the average clerical salary of $8.94/hour (GS-4), the reduction of one-half a person represents a savings of $9,298 per year.

c. Duplicate Tests

When a sample or test result was lost, or a test result delayed, often a repeat (duplicate) test was ordered and performed. By improving information handling, specimen tracking and results reporting, TRILAB was expected to reduce the number of such duplicate tests. No data was available to determine the number of duplicate tests performed by the laboratory; hence the impact of TRILAB in reducing the number of duplicate tests could not be measured directly. Inpatient nursing staff estimated that 40-50 tests per week were avoided, whereas laboratory supervisors estimated the number to be closer to one percent of all tests, i.e., 450 tests per week. Using a conservative estimate, 100 duplicate tests per week (5,200 tests per year) may be avoided due to the implementation of the TRILAB system.

The variable cost of each test, approximately 36¢, was derived from the annual laboratory budget of $1,854,000 (FY 1982 UCA report) divided by the number of tests per year, 2,586,000 and assuming that half the cost was variable. The amount saved per year was therefore $1,872.

d. Summary

The estimated benefits achieved through hours saved in information handling activities was determined in two ways and resulted in two different estimates. Therefore, an average of these estimates was used to approximate the time savings in this area. The reduction of one-half a person at the reception desk and the reduction of duplicate tests, combined with the time savings in information handling, was estimated to be approximately $42,000 (Table 5).

2. Outside the Laboratory Benefits

Interviews were conducted with nursing staff of inpatient units and outpatient clinics to develop estimates of the staff time saved due to implementation of the TRILAB system. An average nursing staff salary of $12.68 per hour was used to determine the value of nursing staff time.

a. Inpatient Units

The nursing staff of six inpatient units with terminals estimated that an average of four staff hours per day per unit were saved in telephone calls, filing and chart review. Since 12 inpatient units had terminals, the total staff time saved was estimated to be 4 x 12 x 365 = 17,520 hours. Using the average nursing staff salary of $12.68, this represented an annual savings of $222,154.

b. Outpatient Services

The nursing staff in the emergency room and four outpatient clinics with terminals estimated that 4.6 hours per day per clinic were saved in telephoning, visiting the laboratory, filing, and looking up results. Six outpatient clinics have terminals, so the estimates of time were multiplied by that number and by the hourly salary figure of $12.68. The estimated savings per year was therefore $127,738.

c. Summary

The total number of hours saved, as estimated by the nursing staff, was 27,594 hours per year. Using the average nursing salary of $12.68, this represents an annual savings of $349,892 (Table 5).

3. Comparison of Costs and Benefits

As indicated in Table 5, estimated annual benefits due to the TRILAB system were approximately $390,000. The majority of these benefits were attributable to savings of time of nursing staff in inpatient and outpatient units which have terminals for results reporting and inquiry.

The benefits compare with the annual estimated costs of approximately $250,000 (Section A), for a net benefit of approximately

$140,000 per year, or $1.1 million over the eight-year life assumed for the system. A more refined cost/benefit life-cycle analysis is presented in the next section, but it is clear that the estimates indicate a high benefit for the TRILAB system.

C. LIFE-CYCLE COST/BENEFIT ANALYSIS OF THE TRILAB SYSTEM AT NRMC OAKLAND

Table 6 presents the "base-case" life-cycle cost and benefit analysis for the TRILAB system at NRMC Oakland. The base-case analysis incorporates the best estimates of costs and benefits, as derived in sections A and B above, and the following assumptions:

- The life-cycle of the system was taken as eight years, beginning in the latter half (six months) of 1982, through the first half of FY 1990, corresponding to the contract period for the system.
- Acquisition and one-time costs were all applied in FY 1982.
- Maintenance costs were as provided in the contract for the system, including the specified escalation factors.
- Staff costs were based on a composite rate using DoD salaries for 1982 and 1983, and were then projected to inflate according to the DoD Index (5.2 percent in 1984, 4.8 percent in 1985, 4.6 percent in 1986; and 4.5 percent thereafter). Space and supplies' costs were estimated to inflate at the same rate as for salaries.
- All costs and benefits after 1983 were discounted at 10 percent per year, according to DoD directives.

As shown in Table 6, total discounted costs for the eight-year life-cycle were estimated at $1.86 million and total discounted benefits were estimated as $2.61 million, for a net benefit of $751,000 over the eight-year life-cycle.

D. NON-QUANTIFIABLE BENEFITS

In addition to the benefits described in the previous sections, which were quantifiable, providers and laboratory staff identified a number of non-quantifiable benefits due to implementation of the TRILAB system, in interviews and in questionnaire surveys carried out as part of the evaluation. These other benefits are described in this section.

TABLE 6

LIFE CYCLE COST AND BENEFIT ANALYSIS FOR THE TRI-SERVICE LABORATORY SYSTEM
AT NAVAL REGIONAL MEDICAL CENTER, OAKLAND - BASE CASE
INFLATION RATES: DOD INDEX
THE DISCOUNT RATE IS 10.00 PERCENT

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
COSTS									
HARDWARE MAINTENANCE	12888.	27580.	29511.	32167.	35062.	39629.	44374.	50587.	28835.
SOFTWARE MAINTENANCE	8340.	16680.	16680.	16680.	16680.	16680.	16680.	16680.	8340.
COMMUNICATION LINES	3348.	7366.	8103.	8913.	9804.	10785.	11863.	13049.	7117.
HARDWARE ACQUISITION	509366.	0.	0.	0.	0.	0.	0.	0.	0.
ON-LINE VENDOR CHARGES	294471.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER EQUIPMENT	1259.	0.	0.	0.	0.	0.	0.	0.	0.
SITE PREPARATION	100000.	0.	0.	0.	0.	0.	0.	0.	0.
SPACE COSTS	1485.	3120.	3280.	1031.	1079.	1127.	1178.	1231.	644.
STAFF COSTS	37111.	77164.	81099.	84792.	88902.	92902.	97083.	101452.	53009.
SUPPLIES	7000.	14714.	15464.	16207.	16952.	17715.	18512.	19345.	10108.
TRAINING TIME	8264.	0.	0.	0.	0.	0.	0.	0.	0.
FILE BUILDING	10578.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	994110.	146624.	154138.	159990.	168479.	178838.	189690.	202344.	108052.
DISCOUNTED TOTAL	994110.	133295.	127387.	120203.	115073.	111045.	107075.	103834.	50407.
TOTAL DISCOUNTED COST =			1862429.						
BENEFITS									
USING LABORATORY	21000.	44000.	46200.	48510.	50741.	53025.	55411.	57904.	30355.
INPATIENT WARDS	111077.	234418.	246408.	258445.	270333.	282498.	295211.	308495.	161189.
OUTPATIENT CLINICS	63869.	134790.	141791.	148605.	155441.	162436.	169746.	177384.	92683.
TOTAL	195946.	413208.	434595.	455560.	476516.	497959.	520367.	543784.	284127.
DISCOUNTED TOTAL	195946.	375644.	359262.	342269.	325462.	309193.	293734.	279047.	132547.
TOTAL DISCOUNTED BENEFITS =			2413099.						
BENEFIT - COST =			550670.						

1. Benefits Achieved in Laboratory

The following discussion of additional benefits of the TRILAB system to laboratory staff is based on interviews and surveys carried out with laboratory administration and supervisors during the implementation monitoring and post-implementation study data collection visits. Laboratory staff identified the following benefits from the system, in addition to those previously discussed:

- Reduction in Transcription Errors. Because abnormal results were highlighted on the CRT screens, and received extra scrutiny by technicians and reviewers, there was potential for reduction of transcription errors. In addition, the Microbiology section had found that the computer-generated "infection control report," which lists Microbiology results by patient, had enabled the section to identify result report format errors. These errors were mostly clerical--that is, where the wording of results could have been improved; only one "blatant" error had been detected during the period of system operation. Thus this review capability, which was not available in the manual system, was used mainly to educate technicians to improve their reporting of Microbiology results.
- Normal Ranges Data. The system provided the capability to provide normal ranges data with each test. This was not always provided previously, at least for the majority of tests for which the users were expected to know what the normal ranges were.
- Search Capability. The availability of the computerized data base of test results and associated demographic data provided the potential capability of performing a variety of analyses with regard to utilization, epidemiologic analysis, etc. This capability had not been utilized as yet.
- Management Reporting. At the time of the post-implementation study, the workload reporting system was being enhanced to provide a more detailed analysis of workload by section, shift

and day of week, and analysis of workload per assigned (FTE) staffing. This would enable laboratory management to improve the allocation of staffing resources in response to workload, and thereby improve the overall efficiency and effectiveness of laboratory services.

2. Provider Benefits

Nursing staff cited the following benefits, in addition to those described previously:

- Improved Morale. As a result of being able to look up test status on the terminal, and the reduction in telephone calls to the laboratory, relationships between nursing and laboratory staff had improved considerably. This had improved morale of both nursing and laboratory staff.
- Decreased Turnaround Time. Turnaround time for test results, especially for routine tests, had been reduced, contributing to the reduction in telephone calls and improvement of relations with the laboratory. This may also have resulted in improved patient care, and reduced length of stay. Although it was not possible to measure the impact on length of stay, it was estimated in a pre-implementation cost/benefit study[2] that reduced turnaround time might reduce the length of stay for 10% of admissions by one day. At 14,600 admissions per year, this would result in a reduction of 1,460 patient days per year. At $100 per day of variable cost, this would imply annual savings of $146,000. (These potential cost savings were not included in the previous analysis of benefits.)
- Identification of Abnormals. Because abnormal results were identified on test results reports (by an asterisk), leading to faster and easier identification of patient problems, patient care was felt to have been improved.

- Discontinuance of Flow Sheets. Since the laboratory test report formats were cumulative, some nursing units discontinued the manual charting of "flow sheets." Other units, however, preferred to maintain them because of their more concise format compared to the computer reports.

Informal interviews were also held with a number of physicians. Physicians were generally pleased with the system, once most of the "bugs" had been eliminated. In general, the house staff (residents and interns) who take care of inpatients, were very pleased with the faster availability of results via terminal inquiry, thereby avoiding the considerable number of phone calls that were previously necessary. Clinic physicians had mixed reactions depending on the extent to which they relied on terminal inquiry, versus review of hard-copy results. Some clinic physicians found it easier to use the terminal to look up patients' results, whereas other physicians preferred to utilize hard-copy reports.

The following benefits were cited by physicians:

- Reduction in Telephone Calls. The number of telephone calls to the laboratory had dropped considerably. It was now necessary to call only when the computer was down, providers needed information for patients who were seen more than 30 days ago, or from units or sites which did not have terminals.
- Improved Turnaround Time. Hard-copy reports were returned to providers sooner, reducing the need for special inquiries on test results.
- Improved Quality of Care. Quality of care had improved because of the report format, including flagging of abnormal values and inclusion of some test results in the daily cumulative summary report which were not included in the flow sheets. Routine values were now available earlier (via terminal inquiry) than prior to TRILAB.

To summarize, both the interviews and the questionnaire surveys indicated that health care providers were generally pleased with the TRILAB system, citing as advantages reduced telephone calls, decreased turnaround times, improvements in relationships with laboratory personnel, and improvement in quality of care due to easier and faster access to test results, identification of abnormal values, and cumulative report formats. A further indirect measure of approval of the system was the expressed desire of staff in those inpatient units and outpatient clinics that did not have terminals (and had to share a terminal in another location) for a terminal in their own location.

3. Summary

In addition to the quantifiable benefits discussed in section B, there were significant additional benefits which could not be quantified. These included:

- Improved turnaround time for test results, most markedly in availability of results for routine Chemistry and Hematology tests. This improved turnaround time in test results had the potential for improving patient care and reducing patient length of stay.
- Laboratory results were more easily available to providers (via terminal inquiry) and in more useful format (provision of cumulative reports and highlighting abnormal results), which had the potential for improving quality of care. In addition, the improved reporting and inquiry capability of the system had resulted in a considerable reduction of telephone calls to the laboratory, improving the relationships between providers and laboratory staff, and reducing the disruptions of work flow in the laboratory.
- The increased management reporting capability within the laboratory had the potential of providing laboratory management with improved data on workload by shift and day of week, and thereby improving the overall efficiency and effectiveness of laboratory services.

IV. SENSITIVITY ANALYSIS

A. INTRODUCTION

In the previous chapter a base-case life-cycle cost/benefit analysis on the TRILAB system at NRMC Oakland was presented using best estimates of costs and benefits, and one set of assumptions with regard to inflation rates and discount rate. In this chapter, sensitivity analyses are presented which investigate the effect on the net benefits of the system due to alternative assumptions with regard to:

- inflation rates;
- discount rate;
- addition of terminals to the system;
- estimated benefits;
- laboratory workload increase.

Individual tables summarizing each cost/benefit analyses are presented in the Appendix, and summarized in this chapter. Table 7 presents a summary of the net benefits and costs of each of the sensitivity analyses, which are discussed below.

1. Inflation Index

The base case utilized the inflation index prescribed by DoD, for operating and maintenance (non-contractual) cost items. The sensitivity of the result to two alternative sets of inflation indices has been determined. One set of inflation rates used was estimated by the Health Care Finance Administration (HCFA), and another set was obtained from the health care industry publication, Rate Controls. The alternative inflation indices are summarized in Table 8. The HCFA projected inflation rates are somewhat higher than those of the DoD inflation indices, and Rate Controls projects somewhat higher rates of inflation than the HCFA projections.

As indicated in Table 7, the result of utilizing the HCFA inflation index is that both costs and benefits are somewhat increased over the base-case estimates, with benefits increasing more than costs. The result is that net benefits (benefits minus costs) are $154,000 greater than the base-case net benefits estimates of $751,000. Similarly, with the Rate Controls indices, the net benefits are $345,000 greater than that of the base-case net benefits.

TABLE 7

SENSITIVITY ANALYSIS OF LIFE-CYCLE COSTS AND BENEFITS
TRILAB SYSTEM AT NRMC OAKLAND
(1982-1990)

	Costs	Benefits	Benefits-Costs
Base Case (10% discount, DoD inflation rates)	$1,862,429	$2,613,099	$ 750,670
Inflation Index			
HCFA inflation indices	1,900,773	2,805,034	904,261
Rate Controls inflation indices	1,943,887	3,038,501	1,094,614
Discount Rate			
8% discount rate	1,930,558	2,800,738	870,180
6% discount rate	2,007,125	3,011,440	1,004,315
Addition of Terminals			
5 Terminals	1,881,520	2,898,782	1,017,262
10 Terminals	1,890,611	3,184,465	1,293,854
Benefits			
75% of outside lab benefits	1,862,429	2,029,428	166,999
50% of outside lab benefits	1,862,429	1,447,745	-414,684
Growth			
7.5% annual volume growth	1,862,429	3,242,815	1,380,386

TABLE 8

INFLATION RATES
(percent per year)

DoD Index[1]	1982-1983	1983-1984	1984-1985	1985-1986	1986-1987	1987-1988	1988-1989	1989-1990
Space Costs	5.1	5.1	4.8	4.6	4.5	4.5	→	→
Supplies	5.1	5.1	4.8	4.6	4.5	4.5	→	→
Nursing Staff	-	5.2	4.8	4.6	4.5	4.5	→	→
Laboratory Staff	-	5.2	4.8	4.6	4.5	4.5	→	→
Civilians	-	5.1	4.8	4.6	4.5	4.5	→	→
HCFA[2]								
Space Costs	6.2	→	→	→	→	→	→	→
Supplies	6.2	→	→	→	→	→	→	→
Nursing Staff	-	7.4	→	→	→	→	→	→
Laboratory Staff	-	7.4	→	→	→	→	→	→
Civilians	-	7.2	→	→	→	→	→	→
Rate Controls[3]								
Space Costs	6.0	6.2	→	→	→	→	→	→
Supplies	6.0	6.2	→	→	→	→	→	→
Nursing Staff	-	10.3	→	→	→	→	→	→
Laboratory Staff	-	10.3	→	→	→	→	→	→
Civilians	-	10.1	→	→	→	→	→	→

1. As shown in DoD Instructions Circular 7041.3 (October 18, 1972)
2. As shown in Rate Control Supplement, February 1983
3. As shown in Rate Control Supplement, February 1983

B. IMPACT OF DISCOUNT RATE

Table 7 shows the impact of utilizing discount rates of 8 percent and 6 percent, instead of the base-case discount rate of 10 percent; the lower discount rates may be more applicable if lower inflation rates hold in the future. With an 8 percent discount rate, the net benefits are $120,000 over that of the base case, and with the 6 percent discount rate net benefits are $254,000 over the base case.

C. CHANGE IN TERMINAL CONFIGURATION

In view of the fact that there was considerable interest at NRMC Oakland in increasing the number of terminals supported by the system, a sensitivity analysis was carried out to estimate the impact of increasing the number of terminals supported by the system by 5 and 10 terminals, assumed to be located in patient care areas.

In addition to the cost of the terminals themselves, it is likely that an additional 16-line ALM, a multiplexing unit that connects the terminal to the computer, would be needed; that additional cabling would be required; and that some additional memory would be required to support the terminals. It was estimated that the cost of the five terminals, the 16-line ALM, cabling and additional memory would involve costs of approximately $21,000. It was estimated that the cost of 10 terminals, the ALM, cabling and additional memory would require an additional $31,000.

In estimating the benefits that would be achieved through the addition of 5 or 10 terminals, it was assumed that the benefits would be conservatively only one-half that of the existing terminals (or savings of only 2 hours of nursing staff time per terminal per day), on the assumption that currently terminals were located in patient units and outpatient clinics with the greatest volume of activity, and that incremental terminals might not result in equivalent staff savings. It was also assumed conservatively that no additional benefits would be achieved in the laboratory (although the volume of telephone calls could be expected to decrease). As indicated in Table 7, the addition of 5 or 10 terminals is estimated to increase net benefits by $267,000 and $543,000, respectively, suggesting that such additional capability would result in a positive net incremental benefit.

D. CHANGE IN BENEFITS

The major component of the benefits estimated for the TRILAB system was the estimated time of nursing staff saved on inpatient care units and in clinics due to the improved results reporting and inquiry capabilities of the system, and improved report formats. The estimated savings were obtained by interviews with nursing staff in a number of units and clinics; the estimates were reasonably consistent from unit to unit and from hospital to hospital (similar estimates were obtained at the other two sites in which TRILAB has been implemented: Wright Patterson Medical Center and Regional Hospital and Dwight D. Eisenhower Army Medical Center). Nevertheless, because of the importance of this component of benefits, a sensitivity analysis was performed by assuming that the actual benefits were only (1) 75 percent of those estimated by nursing staff, and (2) 50 percent of those estimated by nursing staff.

As summarized in Table 7, if benefits outside the laboratory are 75 percent of those estimated, the net benefits are reduced to $167,000 for the eight-year period. If the benefits are assumed to be 50 percent of those estimated, the system costs exceed benefits by $415,000.

E. GROWTH IN VOLUME OF LABORATORY TESTS

The base-case analysis assumed no major increase in volume of tests for the laboratory that would significantly affect system costs or benefits. Between 1980 and 1982, annual volume of tests remained relatively stable at NRMC Oakland. In the future, however, it is possible that test volume will increase, as new tests are developed. In order to test the impact of such an increase in test volume, it was assumed that the volume of tests would increase by 7.5 percent per year after 1983. The major impact of such an increase in volume was assumed to be on benefits achieved in patient care areas, since such factors as number of telephone calls to the laboratory, filing time, etc., would be expected to increase proportionately to number of tests

ordered. It was assumed conservatively that no further benefits would be achieved within the laboratory because many of the benefits are due to reduction of time associated with such tasks as workload and quality control reports, which might be less dependent on number of tests.

As indicated in Table 7, the impact of such an increase in test volume is to increase the net benefits by $630,000 over the eight-year period. Thus the system is expected to have an even higher benefit ratio, if test volume were to increase.

F. SUMMARY

The sensitivity analyses indicate that in general changes in assumptions with regard to inflation rate, discount rate, terminal configuration and test volume have a favorable impact on net benefits, increasing benefits over that of the "base case." Only one scenario--a decrease in time savings in wards and clinics of 50 percent, with all the other base case assumptions intact--produced estimates of costs which exceeded benefits.

REFERENCES

(1) Arthur D. Little, Inc., Evaluation of the Tri-Service Laboratory System, Draft of Volume II, Naval Regional Medical Center, Oakland, Report to TRIMIS Program Office, January 21, 1983.

(2) Cost-Benefit Study for Implementation of the TRILAB Initial Capability System, TRIMIS Program Office, March 1, 1978.

APPENDIX

TABLE A-1

LIFE CYCLE COST AND BENEFIT ANALYSIS FOR THE TRI-SERVICE LABORATORY SYSTEM
AT NAVAL REGIONAL MEDICAL CENTER, OAKLAND--BASE CASE
INFLATION RATES: HCFA
THE DISCOUNT RATE IS 10.00 PERCENT

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
COSTS									
HARDWARE MAINTENANCE	12888.	27580.	29511.	32167.	35062.	39629.	44374.	50587.	28835.
SOFTWARE MAINTENANCE	8340.	16680.	16680.	16680.	16680.	16680.	16680.	16680.	8340.
COMMUNICATION LINES	3348.	7366.	8103.	8913.	9804.	10785.	11863.	13049.	7117.
HARDWARE ACQUISITION	509366.	0.	0.	0.	0.	0.	0.	0.	0.
ONE-TIME VENDOR CHARGES	294471.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER EQUIPMENT	1259.	0.	0.	0.	0.	0.	0.	0.	0.
SITE PREPARATION	100000.	0.	0.	0.	0.	0.	0.	0.	0.
SPACE COSTS	1485.	3153.	3349.	1067.	1133.	1204.	1278.	1358.	721.
STAFF COSTS	37111.	77164.	82720.	88676.	95060.	101905.	109242.	117107.	62769.
SUPPLIES	7000.	14868.	15790.	16769.	17808.	18913.	20085.	21330.	11326.
TRAINING TIME	8264.	0.	0.	0.	0.	0.	0.	0.	0.
FILE BUILDING	10578.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	994110.	146811.	156153.	164271.	175548.	189115.	203522.	220112.	119109.
DISCOUNTED TOTAL	994110.	133465.	129052.	123420.	119901.	117426.	114883.	112952.	55565.
TOTAL DISCOUNTED COST =			1900773.						
BENEFITS									
INSIDE LABORATORY	21000.	44000.	47256.	50753.	54509.	58542.	62874.	67527.	36262.
INPATIENT WARDS	111077.	234418.	251765.	270396.	290405.	311895.	334975.	359763.	193193.
OUTPATIENT CLINICS	63869.	134790.	144764.	155477.	166982.	179339.	192610.	206863.	111086.
TOTAL	195946.	413208.	443785.	476626.	511896.	549776.	590460.	634154.	340540.
DISCOUNTED TOTAL	195946.	375644.	366765.	359096.	349632.	341368.	333299.	325421.	158865.
TOTAL DISCOUNTED BENEFITS =			2805034.						
BENEFITS - COSTS =			904261.						

TABLE A-2

LIFE CYCLE COST AND BENEFIT ANALYSIS FOR THE TRI-SERVICE LABORATORY SYSTEM
AT NAVAL REGIONAL MEDICAL CENTER, OAKLAND--BASE CASE
INFLATION RATES: RATE CONTROL SUPPLEMENT
THE DISCOUNT RATE IS 10.00 PERCENT

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
COSTS									
HARDWARE MAINTENANCE	12888.	27580.	29511.	32167.	35062.	39629.	44374.	50587.	28835.
SOFTWARE MAINTENANCE	8340.	16680.	16680.	16680.	16680.	16680.	16680.	16680.	8340.
COMMUNICATION LINES	3348.	7366.	8103.	8913.	9804.	10785.	11863.	13049.	7117.
HARDWARE ACQUISITION	509366.	0.	0.	0.	0.	0.	0.	0.	0.
ONE-TIME VENDOR CHARGES	294471.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER EQUIPMENT	1259.	0.	0.	0.	0.	0.	0.	0.	0.
SITE PREPARATION	100000.	0.	0.	0.	0.	0.	0.	0.	0.
SPACE COSTS	1485.	3147.	3342.	1065.	1131.	1201.	1276.	1355.	719.
STAFF COSTS	37111.	77164.	84958.	93538.	102986.	113387.	124839.	137448.	75665.
SUPPLIES	7000.	14840.	15760.	16737.	17775.	18877.	20047.	21290.	11305.
TRAINING TIME	8264.	0.	0.	0.	0.	0.	0.	0.	0.
FILE BUILDING	10578.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	994110.	146777.	158354.	169100.	183438.	200559.	219080.	240409.	131981.
DISCOUNTED TOTAL	994110.	133434.	130871.	127048.	125290.	124531.	123665.	123368.	61570.
TOTAL DISCOUNTED COST =			1943387.						
BENEFITS									
INSIDE LABORATORY	21000.	44000.	48532.	53531.	59044.	65126.	71834.	79233.	43697.
INPATIENT WARDS	111077.	234418.	258563.	285195.	314570.	346971.	382709.	422128.	232804.
OUTPATIENT CLINICS	63869.	134790.	148673.	163987.	180877.	199508.	220057.	242723.	133862.
TOTAL	195946.	413208.	455768.	502713.	554492.	611605.	674600.	744084.	410362.
DISCOUNTED TOTAL	195946.	375644.	376668.	377695.	378725.	379758.	380794.	381833.	191437.
TOTAL DISCOUNTED BENEFITS =			3038501.						
BENEFITS - COSTS =			1094614.						

TABLE A-3

LIFE CYCLE COST AND BENEFIT ANALYSIS FOR THE TRI-SERVICE LABORATORY SYSTEM
AT NAVAL REGIONAL MEDICAL CENTER, OAKLAND--BASE CASE
INFLATION RATES: DOD INDEX
THE DISCOUNT RATE IS 8.00 PERCENT

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
COSTS									
HARDWARE MAINTENANCE	12888.	27580.	29511.	32167.	35062.	39629.	44374.	50587.	28835.
SOFTWARE MAINTENANCE	8340.	16680.	16680.	16680.	16680.	16680.	16680.	16680.	8340.
COMMUNICATION LINES	3348.	7366.	8103.	8913.	9804.	10785.	11863.	13049.	7117.
HARDWARE ACQUISITION	509366.	0.	0.	0.	0.	0.	0.	0.	0.
ONE-TIME VENDOR CHARGES	294471.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER EQUIPMENT	1259.	0.	0.	0.	0.	0.	0.	0.	0.
SITE PREPARATION	100000.	0.	0.	0.	0.	0.	0.	0.	0.
SPACE COSTS	1485.	3120.	3280.	1031.	1079.	1127.	1178.	1231.	644.
STAFF COSTS	37111.	77164.	81099.	84992.	88902.	92902.	97083.	101452.	53009.
SUPPLIES	7000.	14714.	15464.	16207.	16952.	17715.	18512.	19345.	10108.
TRAINING TIME	8264.	0.	0.	0.	0.	0.	0.	0.	0.
FILE BUILDING	10578.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	994110.	146624.	154138.	159990.	168479.	178838.	189690.	202344.	108052.
DISCOUNTED TOTAL	994110.	135763.	132148.	127005.	123837.	121714.	119537.	118066.	58377.
TOTAL DISCOUNTED COST =			1930558.						
BENEFITS									
INSIDE LABORATORY	21000.	44000.	46288.	48510.	50741.	53025.	55411.	57904.	30255.
INPATIENT WARDS	111077.	234418.	246608.	258445.	270333.	282498.	295211.	308495.	161189.
OUTPATIENT CLINICS	63869.	134790.	141799.	148685.	155441.	162436.	169746.	177384.	92683.
TOTAL	195946.	413208.	434695.	455640.	476516.	497959.	520367.	543784.	284127.
DISCOUNTED TOTAL	195946.	382600.	372601.	361638.	350253.	338903.	327920.	317293.	153505.
TOTAL DISCOUNTED BENEFITS =			2800738.						
BENEFITS - COSTS =			870180.						

TABLE A-4

LIFE CYCLE COST AND BENEFIT ANALYSIS FOR THE TRI-SERVICE LABORATORY SYSTEM
AT NAVAL REGIONAL MEDICAL CENTER, OAKLAND--BASE CASE
INFLATION RATES: DOD INDEX
THE DISCOUNT RATE IS 6.00 PERCENT

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
COSTS									
HARDWARE MAINTENANCE	12888.	27580.	29511.	32167.	35062.	39629.	44374.	50587.	28835.
SOFTWARE MAINTENANCE	8340.	16680.	16680.	16680.	16680.	16680.	16680.	16680.	8340.
COMMUNICATION LINES	3348.	7366.	8103.	8913.	9804.	10785.	11863.	13049.	7117.
HARDWARE ACQUISITION	509366.	0.	0.	0.	0.	0.	0.	0.	0.
ONE-TIME VENDOR CHARGES	294471.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER EQUIPMENT	1259.	0.	0.	0.	0.	0.	0.	0.	0.
SITE PREPARATION	100000.	0.	0.	0.	0.	0.	0.	0.	0.
SPACE COSTS	1485.	3120.	3280.	1031.	1079.	1127.	1178.	1231.	644.
STAFF COSTS	37111.	77164.	81099.	84992.	88902.	92902.	97083.	101452.	53009.
SUPPLIES	7000.	14714.	15464.	16207.	16952.	17715.	18512.	19345.	10108.
TRAINING TIME	8264.	0.	0.	0.	0.	0.	0.	0.	0.
FILE BUILDING	10578.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	994110.	146624.	154138.	159990.	168479.	178838.	189690.	202344.	108052.
DISCOUNTED TOTAL	994110.	138325.	137182.	134331.	133451.	133639.	133724.	134570.	67793.
TOTAL DISCOUNTED COST =			2007125.						
BENEFITS									
INSIDE LABORATORY	21000.	44000.	46289.	48510.	50741.	53025.	55411.	57904.	30255.
INPATIENT WARDS	111077.	234418.	246608.	258445.	270333.	282498.	295211.	308495.	161189.
OUTPATIENT CLINICS	63869.	134790.	141799.	148605.	155441.	162436.	169746.	177384.	92683.
TOTAL	195946.	413208.	434695.	455560.	476516.	497959.	520367.	543784.	284127.
DISCOUNTED TOTAL	195946.	389819.	386827.	382492.	377445.	372104.	366839.	361642.	178245.
TOTAL DISCOUNTED BENEFITS =			3011440.						
BENEFITS - COSTS			1004315.						

TABLE A-5

LIFE CYCLE COST AND BENEFIT ANALYSIS FOR THE TRI-SERVICE LABORATORY SYSTEM
AT NAVAL REGIONAL MEDICAL CENTER,OAKLAND--CASE 1: PLUS FIVE TERMINALS
INFLATION RATES: DOD INDEX
THE DISCOUNT RATE IS 10.00 PERCENT

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
COSTS									
HARDWARE MAINTENANCE	12883.	27580.	29511.	32167.	35062.	39629.	44374.	50587.	28835.
SOFTWARE MAINTENANCE	8340.	16680.	16680.	16680.	16680.	16680.	16680.	16680.	8340.
COMMUNICATION LINES	3348.	7366.	8103.	8913.	9804.	10785.	11863.	13049.	7117.
HARDWARE ACQUISITION	509366.	21000.	0.	0.	0.	0.	0.	0.	0.
ONE-TIME VENDOR CHARGES	294471.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER EQUIPMENT	1259.	0.	0.	0.	0.	0.	0.	0.	0.
SITE PREPARATION	100000.	0.	0.	0.	0.	0.	0.	0.	0.
SPACE COSTS	1485.	3120.	3280.	1031.	1079.	1127.	1178.	1231.	644.
STAFF COSTS	37111.	77164.	81099.	84992.	88902.	92902.	97033.	101452.	53009.
SUPPLIES	7000.	14714.	15464.	16207.	16952.	17715.	18512.	19345.	10108.
TRAINING TIME	8264.	0.	0.	0.	0.	0.	0.	0.	0.
FILE BUILDING	10578.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	994110.	167624.	154138.	159990.	168479.	178838.	189690.	202344.	108052.
DISCOUNTED TOTAL	994110.	152385.	127387.	120203.	115073.	111045.	107075.	103834.	50407.
TOTAL DISCOUNTED COST =			1881520.						
BENEFITS									
INSIDE LABORATORY	21000.	44000.	46288.	48510.	50741.	53025.	55411.	57904.	30255.
INPATIENT WARDS	111077.	234418.	246608.	258445.	270333.	282498.	295211.	308495.	161189.
OUTPATIENT CLINICS	63869.	134790.	141799.	148605.	155441.	162436.	169746.	177384.	92683.
ADDITIONAL TERMINALS	0.	48837.	51377.	54841.	56419.	58854.	61502.	64270.	33581.
TOTAL	195946.	462045.	486071.	509403.	532835.	556813.	581869.	608054.	317708.
DISCOUNTED TOTAL	195946.	420041.	401212.	382722.	363944.	345737.	328450.	312028.	148213.
TOTAL DISCOUNTED BENEFITS =			2908292.						
BENEFITS - COSTS =			1026772.						

TABLE A-6

LIFE CYCLE COST AND BENEFIT ANALYSIS FOR THE TRI-SERVICE LABORATORY SYSTEM
AT NAVAL REGIONAL MEDICAL CENTER,OAKLAND--CASE 2: PLUS TEN TERMINALS
INFLATION RATES: DOD INDEX
THE DISCOUNT RATE IS 10.00 PERCENT

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
COSTS									
HARDWARE MAINTENANCE	12888.	27580.	29511.	32167.	35062.	39629.	44374.	50587.	28835.
SOFTWARE MAINTENANCE	8340.	16680.	16680.	16680.	16680.	16680.	16680.	16680.	8340.
COMMUNICATION LINES	3348.	7366.	8103.	8913.	9804.	10785.	11863.	13049.	7117.
HARDWARE ACQUISITION	509366.	31000.	0.	0.	0.	0.	0.	0.	0.
ONE-TIME VENDOR CHARGES	294471.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER EQUIPMENT	1259.	0.	0.	0.	0.	0.	0.	0.	0.
SITE PREPARATION	100000.	0.	0.	0.	0.	0.	0.	0.	0.
SPACE COSTS	1485.	3120.	3280.	1031.	1079.	1127.	1178.	1231.	644.
STAFF COSTS	37111.	77164.	81099.	84992.	88902.	92902.	97083.	101452.	53009.
SUPPLIES	7000.	14714.	15464.	16207.	16952.	17715.	18512.	19345.	10108.
TRAINING TIME	8264.	0.	0.	0.	0.	0.	0.	0.	0.
FILE BUILDING	10578.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	994110.	177624.	154138.	159990.	168479.	178838.	189690.	202344.	108052.
DISCOUNTED TOTAL	994110.	161476.	127387.	120203.	115073.	111045.	107075.	103834.	50407.

TOTAL DISCOUNTED COST = 1890611.

BENEFITS									
INSIDE LABORATORY	21000.	44000.	46288.	48510.	50741.	53025.	55411.	57904.	30255.
INPATIENT WARDS	111077.	234418.	246608.	258445.	270333.	282498.	295211.	308495.	161189.
OUTPATIENT CLINICS	63869.	134790.	141799.	148605.	155441.	162436.	169746.	177384.	92683.
ADDITIONAL TERMINALS	0.	97674.	102754.	107685.	112639.	117707.	123004.	128539.	67162.
TOTAL	195946.	510882.	537448.	563245.	589155.	615667.	643372.	672323.	351289.
DISCOUNTED TOTAL	195946.	464438.	444172.	423175.	402401.	382281.	363166.	345008.	168879.

TOTAL DISCOUNTED BENEFITS = 3189465.

BENEFITS - COSTS = 1298854.

TABLE A-7

LIFE CYCLE COST AND BENEFIT ANALYSIS FOR THE TRI-SERVICE LABORATORY SYSTEM
AT NAVAL REGIONAL MEDICAL CENTER, OAKLAND--CASE 3: 75% OF OUTSIDE LAB BENEFITS
INFLATION RATES: DOD INDEX
THE DISCOUNT RATE IS 10.00 PERCENT

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
COSTS									
HARDWARE MAINTENANCE	12888.	27580.	29511.	32167.	35062.	39629.	44374.	50587.	28835.
SOFTWARE MAINTENANCE	8340.	16680.	16680.	16680.	16680.	16680.	16680.	16680.	8340.
COMMUNICATION LINES	3348.	7366.	8103.	8913.	9804.	10785.	11863.	13049.	7117.
HARDWARE ACQUISITION	509366.	0.	0.	0.	0.	0.	0.	0.	0.
ONE-TIME VENDOR CHARGES	294471.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER EQUIPMENT	1259.	0.	0.	0.	0.	0.	0.	0.	0.
SITE PREPARATION	100000.	0.	0.	0.	0.	0.	0.	0.	0.
SPACE COSTS	1485.	3120.	3280.	1031.	1079.	1127.	1178.	1231.	644.
STAFF COSTS	37111.	77164.	81099.	84992.	88902.	92902.	97083.	101452.	53009.
SUPPLIES	7000.	14714.	15464.	16207.	16952.	17715.	18512.	19345.	10108.
TRAINING TIME	8264.	0.	0.	0.	0.	0.	0.	0.	0.
FILE BUILDING	10578.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	994110.	146624.	154138.	159990.	168479.	178838.	189690.	202344.	108052.
DISCOUNTED TOTAL	994110.	133295.	127387.	120203.	115073.	111045.	107075.	103834.	50407.

TOTAL DISCOUNTED COST = 1862429.

BENEFITS

INSIDE LABORATORY	21000.	44000.	46288.	48510.	50741.	53025.	55411.	57904.	30255.
INPATIENT WARDS	83308.	175814.	184956.	193831.	202751.	211874.	221409.	231372.	120892.
OUTPATIENT CLINICS	47902.	101093.	106350.	111455.	116502.	121828.	127310.	133039.	69513.
TOTAL	152210.	320907.	337594.	353796.	370074.	386727.	404129.	422315.	220660.
DISCOUNTED TOTAL	152210.	291734.	279003.	265814.	252765.	240127.	228121.	216714.	102939.

TOTAL DISCOUNTED BENEFITS = 2029428.

BENEFITS - COSTS = 166999.

TABLE A-8

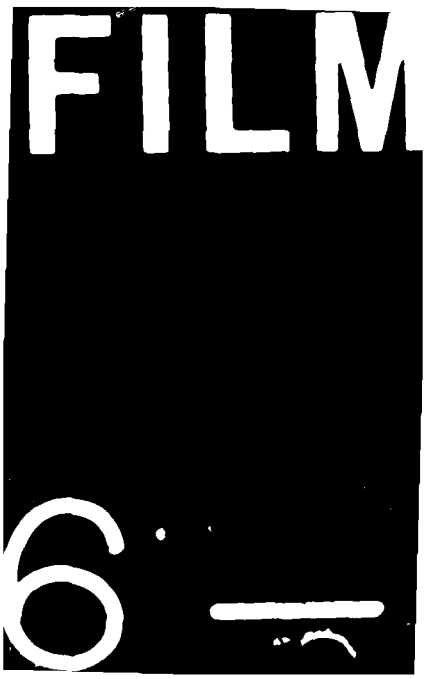
LIFE CYCLE COST AND BENEFIT ANALYSIS FOR THE TRI-SERVICE LABORATORY SYSTEM
AT NAVAL REGIONAL MEDICAL CENTER, OAKLAND--CASE 4: 50% OF OUTSIDE LAB BENEFITS
INFLATION RATES: DOD INDEX
THE DISCOUNT RATE IS 10.00 PERCENT

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
COSTS									
HARDWARE MAINTENANCE	12888.	27580.	29511.	32167.	35062.	39629.	44374.	50587.	28835.
SOFTWARE MAINTENANCE	8340.	16680.	16680.	16680.	16680.	16680.	16680.	16680.	8340.
COMMUNICATION LINES	3348.	7366.	8103.	8913.	9804.	10785.	11863.	13049.	7117.
HARDWARE ACQUISITION	509366.	0.	0.	0.	0.	0.	0.	0.	0.
ONE-TIME VENDOR CHARGES	294471.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER EQUIPMENT	1259.	0.	0.	0.	0.	0.	0.	0.	0.
SITE PREPARATION	100000.	0.	0.	0.	0.	0.	0.	0.	0.
SPACE COSTS	1485.	3120.	3280.	1031.	1079.	1127.	1178.	1231.	644.
STAFF COSTS	37111.	77164.	81099.	84992.	88902.	92902.	97083.	101452.	53009.
SUPPLIES	7000.	14714.	15464.	16207.	16952.	17715.	18512.	19345.	10108.
TRAINING TIME	8264.	0.	0.	0.	0.	0.	0.	0.	0.
FILE BUILDING	10578.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	994110.	146624.	154138.	159990.	168479.	178838.	189690.	202344.	108052.
DISCOUNTED TOTAL	994110.	133295.	127387.	120203.	115073.	111045.	107075.	103834.	50407.
TOTAL DISCOUNTED COST =			1862429.						
BENEFITS									
OUTSIDE LABORATORY	21000.	44000.	46288.	48510.	50741.	53025.	55411.	57904.	30255.
INPATIENT WARDS	55539.	117209.	123304.	129222.	135167.	141249.	147605.	154248.	80594.
OUTPATIENT CLINICS	33935.	67395.	70900.	74303.	77721.	81218.	84873.	88692.	46342.
TOTAL	110474.	228604.	240491.	252035.	263629.	275492.	287889.	300844.	157191.
DISCOUNTED TOTAL	110474.	207822.	198753.	189358.	180062.	171059.	162506.	154381.	73331.
TOTAL DISCOUNTED BENEFITS =			1447746.						
BENEFITS - COSTS =			-414684.						

TABLE A-9

LIFE CYCLE COST AND BENEFIT ANALYSIS FOR THE TRI-SERVICE LABORATORY SYSTEM
AT NAVAL REGIONAL MEDICAL CENTER, OAKLAND --CASE 5: WORKLOAD GROWTH RATE
THE WORKLOAD INCREASE AT 7.50 PERCENT ANNUALLY
INFLATION RATES: DOD INDEX
THE DISCOUNT RATE IS 10.00 PERCENT

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
COSTS									
HARDWARE MAINTENANCE	12888.	27580.	29511.	32167.	35062.	39629.	44374.	50587.	28835.
SOFTWARE MAINTENANCE	8340.	16680.	16680.	16680.	16680.	16680.	16680.	16680.	8340.
COMMUNICATION LINES	3348.	7366.	8103.	8913.	9804.	10785.	11863.	13049.	7117.
HARDWARE ACQUISITION	509366.	0.	0.	0.	0.	0.	0.	0.	0.
ONE-TIME VENDOR CHARGES	294471.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER EQUIPMENT	1259.	0.	0.	0.	0.	0.	0.	0.	0.
SITE PREPARATION	100000.	0.	0.	0.	0.	0.	0.	0.	0.
SPACE COSTS	1485.	3120.	3280.	1031.	1079.	1127.	1178.	1231.	644.
STAFF COSTS	37111.	77164.	81099.	84992.	88902.	92902.	97083.	101452.	53009.
SUPPLIES	7000.	14714.	15464.	16207.	16952.	17715.	18512.	19345.	10108.
TRAINING TIME	8264.	0.	0.	0.	0.	0.	0.	0.	0.
FILE BUILDING	10578.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	994110.	146624.	154138.	159990.	168479.	178838.	189690.	202344.	108052.
DISCOUNTED TOTAL	994110.	133295.	127387.	120203.	115073.	111045.	107075.	103834.	50407.
TOTAL DISCOUNTED COST =			1862429.						
BENEFITS									
INSIDE LABORATORY	21000.	44000.	49760.	56059.	63036.	70813.	79549.	89364.	50194.
INPATIENT WARDS	111077.	234418.	265103.	298665.	335834.	377268.	423813.	476101.	267420.
OUTPATIENT CLINICS	63869.	134790.	152434.	171732.	193104.	216929.	243692.	273758.	153766.
TOTAL	195946.	413208.	467297.	526457.	591974.	665009.	747055.	839223.	471381.
DISCOUNTED TOTAL	195946.	375644.	386196.	395535.	404326.	412918.	421693.	430654.	219903.
TOTAL DISCOUNTED BENEFITS =			3242815.						
BENEFITS - COSTS =			1380386.						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